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Limnology of Surinsar lake, Jammu (J&K State): Part I- Protozoa

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Abstract: Zooplanktonic analysis of Surinsar lake, Jammu, during the year 2002-2004, has shown the presence of fifty one species of protozoans belonging to three classes viz. Sarcodina (32 spp), Ciliata (16 spp.) and Mastigophora (3 spp.). Quantitatively, during the year 2002-03, there was dominance of Sarcodina followed by Ciliata and Mastigophra. In the subsequent year viz. 2003-04, the order of quantitative dominance has been observed as Ciliata> Sarcodina and> Mastigophora. Coefficient of correlation(r) of protozoans with various physico-chemical parameters has generally shown insignificant results. The calculated value of ANOVA of various protozoan classes was significant and the means of various classes differed significantly among themselves indicating their significant contribution to total protozoan population.

Keywords: Lake , Zooplankton, Protozoa, Correlation, Diversity Index

INTRODUCTION

Protozoans are cosmopolitan in distribution, predominantly microscopic, simplest in structure and the most abundant animals in the world in terms of number and biomass. These biological indicators(Katiyar and Belsare,1997; Xu *et al*., 2002; Lee *et al*., 2004 and Jiang and Shen, 2007), also play a significant role in biological wastewater treatment (Kotangale, 1995; Lee *et al*., 2004 and Jiang and Shen, 2007). Unlike water quality measurements, which only provide an instantaneous assessment of lake conditions, protozoan community can be used to identity past disturbances and toxic effects that are not readily detected by chemical means (Cairns and McCormick, 1993). Inspite of a major role played by these microscopic organisms in aquatic environment, protozoans are, probably, the least studied group of fresh water. The present detailed study is first in this direction from a subtropical lake- Surinsar, in Siwalik hills, Jammu.

TOPOGRAPHY OF THE AREA

Jammu region of J&K state has two important freshwater Siwalik lakes viz. Mansar and Surinsar. Surinsar- a subtropical fresh water lake is about 25 km North-east of Jammu city(J & K). It is situated at an elevation of 605 meters, in 75^0 02' 303 East Longitude and 32^0 46' 303 North Latitude. The spread of the lake varies from 27.14 ha (peak summer) to 27.92 ha (monsoons). The water level of the lake oscillates by 1.20m and touches its peak during monsoon.

The littoral zone of lake has thick vegetation cover of emergent plants like *Typha fatifolia, Phragmites* sp., *Ipomea cornea, Scirpus* sp., floating vegetation like *Nelumbium* sp. *and Nymphoides* sp. and submerged vegetation comprising of *Hydrilla verticillata, Najas graminae, Ceratophyllum demersum , Potamogeton crispus, P. nodosus, Chara fragalis, C. zeylanica, C. brauni, Nitella* sp. *etc.* Fish fauna include *Puntius conconius, P.ticto, P. chola, P. sophore, Rasbora rasbora, Channa punctatus and Heteropneustus fossilis.* In addition, the lake supports two important species of turtles viz. *Trionyx gangeticus* and *Lissemys punctata* an endangered species (CITES and IUCN Red listed).

This lake is rich in micro-nutrients for which it is an attractive habitat, breeding and nursery ground for many migratory waterfowls. Important bird fauna(both native and migratory birds) of the lake includes *Fulica atra atra*(Coot), *Gallinula chloropus indicus*(Indian moorhen), *Podiceps nigricollis, Podiceps cristatus*(Great Crested Grebe), *Podiceps ruficollis* (Dabchick), *Podiceps cristatus* (Great crested Grebe), *Aythya fuligula* (Pochard), *Netta rufina* (Red Crested Pochard), *Anas platyrhyncha platyrhyncha* (Mallard or Wild Duck), *Anas clypeata*(Shoveller), *Anas acuta*(Pintail), *Anas crecca*(Common Teal), *Phalacrocorax niger* (little Cormorant), *P.corbo* (large Cormorant), *Egretta intermedia* (Median egret), *E. garzetta*(little egret), *Ardea alba* (Large egret), *Ardeola grayii* (Pond heron), *A. cinerea* (Grey heron), *Ceryle lugubris guttulata*(Pied Kingfisher) and *Alcedo atthis*(Small blue kingfisher).

MATERIALS AND METHODS

Monthly planktonic samples, during the year 2002-03/ 2003-04, were collected by filtering 5 litres of water through a planktonic net (no. 25) in labeled plastic tubes. For live study and identification, separate samples were collected in a similar manner. Samples collected were fixed in 5% formaldehyde solution in labeled glass tubes, identified (Naidu, 1966; Nair *et al.,* 1971; Dutta, 1983; Kudo, 1986 and Edmondson, 1992) and counted (n/l) by drop count method(Welch, 1948). Coefficient of correlation(r) and analysis of variance have been calculated following standard methods(Trivedy *et al.* ,1987 and Khan and Khanam, 2004).

RESULTS AND DISCUSSION

Fifty one species of protozoans, identified in lake Surinsar, have shown the qualitative dominance of class Sarcodina followed by Ciliata and Mastigophora (Tables 1 and 2). Sehgal (1980) observed two species viz. *Difflugia* sp. and *Centropyxis* sp. from Lake Surinsar, Jammu. Sharma(2000) analyzed zooplanktonic fauna of lake Mansar, Jammu and reported five species viz. *Amphisiella oblonga, Centropyxis aculeate, Difflugia* sp., *Nuclearia* sp. and *Vorticella* sp. Contrary to the present observation, Katiyar and Belsare(1997) noticed qualitative dominance of Mastigophora(24 spp.) followed by Ciliata(8 spp.) and Sarcodina(8 spp.), from Bhopal lakes, India and Kaushik and Saksena(1995) reported only class Sarcodina(6 spp.) from Gwalior .

Qualitative analysis of Protozoa has revealed the seasonal presence of various genera belonging to different classes. Earlier, Jhingran (1991) also documented seasonal planktonic association in tropical and sub-tropical climates. He pointed out that certain planktonic forms disappear at the specific periods and re-appear during others. Such temporary disappearances may be due to the fact that the species concerned either become too scarce or occur as spores or resting eggs etc. which are not easily detectable. Upon the return of the favourable conditions these plankters multiply and thus, increase in number.

Among the various genera of Mastigophora, during the first year, *Euglena* recorded its presence six times and *Phacus* and *Chlamydomonas* four times each (Table 1). In the subsequent year, *Euglena* is noticed nine times and *Phacus* and *Chlamydomonas* thrice each (Table 2).

Seasonal qualitative analysis of class Mastigophora has revealed March and April high diversity with July, November, December and January disappearance, during the year 2002-03(Table 1). In the subsequent year viz. 2003-04, these recorded April and May increased diversity with complete disappearance during July, August and November (Table 2).

Among various genera of rhizopod protozoan, belonging to class Sarcodina, during the first year of study, only *Arcella* showed its perennial presence. *Difflugia* and *Centopyxis* recorded their presence ten times; *Euglypha* nine times; *Nebela* six times; *Pyxidicula* four times; *Lesquereusia, Bullinula* and *Astrameoba* thrice each and *Pareuglypha*, *Plagiopyxis* and *Ameoba* twice each. Among the Actinopod protozoans, *Actinophrys* is seen only once(Table 1). During the subsequent year, among various genera of rhizopod protozoans, *Arcella, Difflugia* and *Centropyxis* remained perennial in the planktonic samples. Genus *Euglypha* was observed eleven times; *Lesquereusia*, ten times; *Ameoba* seven times; *Plagiopyxis* and *Pyxidicula* six times*; Bullinula, Nebela* and *Astrameoba* five times each and *Pareuglypha* once. Among the actinopod protozoans, *Actinophrys* made its record four times (Table 2).

Qualitative dominance of *Difflugia* over other genus of class Sarcodina, as observed in the present analysis of Surinsar lake water, is in accordance with the findings of Verma and Dalela(1974), Sharma and Rathore(2000) and Narayana and Somashekar(2002). Qualitative richness of various rhizopod species such as *Difflugia, Centropyxis* and *Arcella* in Surinsar lake water, may be due to their high tolerance to organic enrichment and is in agreement with the findings of Verma and Dalela (1974), Mishra and Saksena(1990), Srivastava *et al*.(1990), Kaushik and Saksena (1995) and Wetzel (2000).

An observation of Table 1 reveals April, May highest and December lowest qualitative diversity of class Sarcodina, during the first year. In the subsequent year, these recorded bimodal viz. March, April, September and October increase with March and April highest and November lowest diversity (Table 2).

Genus *Euplotes*, among various genera of class Ciliata, during the year 2002-03, showed its presence eight times; *Paramecium* seven times*; Vorticella*, *Coleps* and *Stylonychia* six times; *Urocentrum* and *Carchesium* four times, *Halteria and Condylostoma* thrice and *Lionotus*, *Uronema* and *Homalozoon* twice each(Table 1). During the subsequent year viz. 2003-04, genus *Paramecium* remained perennial; *Urocentrum* made its presence ten times*; Vorticella* and *Euplotes* nine times*; Coleps* eight times; *Stylonychia* and *Carchesium* six times; *Halteria* five times*; Lionotus* four times, *Chilodonella, Uronema, Homalozoon* and *Condylostoma* thrice each (Table 2).

Ciliates, qualitatively, during both the years, recorded March-May increase with a continuous decline from May onwards upto January. These observed April/April highest and January/ February lowest qualitative record. Seasonally, protozoan qualitative diversity remained high during summer (March-May), with April highest record, during both the years of study. These observed November, December and January/ November and December trough with lowest qualitative count during November (Tables 1 and 2).

Quantitatively, total protozoans, ranged between 59±53.18n/l (December) to 1540±554.73n/l (April) during the first year and 414±128.49n/l (July) to 2538±783.40n/l (April) in the subsequent year of study.

Table 1. Mean monthly variations in Protozoa of Surinsar Lake, Jammu. (Feb 2002-Jan 2003)

Name of the species	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
PROTOZOA												
Class Mastigophora												
Euglena sp.	15 ± 13.74	26 ± 14.49	22 ± 36.38	-	-	-	3 ± 8.34	16 ± 30.32	15 ± 29.30	-	-	-
Chlamydomonas sp.	-	17 ± 32.51	27 ± 35.41	34 ± 81.40	12 ± 21.31	-	-	-	-	-	-	-
Phacus sp.	-	54 ± 65.17	32 ± 50.99	21 ± 52.69	-	-	-	23 ± 22.57	-	-	-	-
Total Mastigophora	15 ± 13.74	97 ± 59.06	81 ± 64.44	55 ± 88.67	12 ± 21.31	±	3 ± 8.34	39 ± 43.43	15 ± 29.30	-	-	-
Class Sarcodina												
Arcella discoides	21 ± 9.12	-	119 ± 66.14	69 ± 35.30	15 ± 19.12	19 ± 16.70	-	-	22 ± 17.72	54 ± 51.47	-	-
A.vulgaris	32 ± 17.73	62 ± 58.17	83 ± 42.08	24 ± 18.35	12 ± 10.29	-	-	-	27 ± 12.46	44 ± 32.77	-	-
A.polypora	-	8 ± 19.51	76 ± 90.72	-	-	-	-	-	-	-	-	-
A.megastoma	-	-	53 ± 54.43	32 ± 39.22	-	22 ± 32.51	12 ± 27.08	-	-	-	-	-
A.dentata	-	-	125 ± 95.19	54 ± 27.52	-	-	-	-	-	-	-	-
Arcella sp.	-	39 ± 48.90	17 ± 53.50	8 ± 22.50	-	-	-	-	-	-	-	-
Total Arcella	53 ± 22.19	109 ± 75.42	473 ± 178.67	187 ± 75.20	27 ± 26.71	41 ± 25.53	12 ± 27.08	-	49 ± 21.69	98 ± 48.21	-	-
Difflugia urceolata	39 ± 13.79	66 ± 43.90	43 ± 43.05	33 ± 37.90	29 ± 8.36	44 ± 45.16	40 ± 18.15	33 ± 13.58	6 ± 19.63	-	-	13 ± 31.97
D.acuminata	25 ± 12.48	53 ± 53.10	74 ± 118.02	52 ± 48.94	49 ± 59.99	12 ± 13.15	59 ± 35.40	47 ± 29.21	-	-	-	12 ± 27.30
D.oblonga	18 ± 27.44	33 ± 33.84	39 ± 26.45	55 ± 31.07	26 ± 15.16	31 ± 22.29	65 ± 35.55	42 ± 23.78	-	-	-	8 ± 14.64
D.corona	15 ± 21.45	0 ± 0.00	-	-	-	8 ± 28.00	39 ± 64.95	31 ± 44.26	-	-	-	6 ± 22.23
D.lebes	35 ± 30.53	0 ± 0.00	-	18 ± 24.61	-	-	-	14 ± 13.42	-	-	-	11 ± 18.91
D.rubescens	5 ± 10.72	3 ± 9.81	-	-	-	-	-	12 ± 16.65	-	-	-	7 ± 23.38
D.tuberculata	-	7 ± 15.98	-	45 ± 49.99	-	-	-	-	-	-	-	12 ± 16.51
Difflugia sp.	-	-	-	-	-	-	-	-	8 ± 19.88	-	-	3 ± 9.35
Total Difflugia	135 ± 43.25	162 ± 76.00	156 ± 95.62	203 ± 66.10	104 ± 73.97	95 ± 46.90	183 ± 59.68	179 ± 74.42	14 ± 26.05	-	-	72 ± 52.36
Centropyxis aculeata	15 ± 18.01	11 ± 28.34	112 ± 59.05	106 ± 76.84	77 ± 51.08	23 ± 9.86	66 ± 22.62	21 ± 47.49	28 ± 42.41	21 ± 20.32	-	-
C.hemisphaerica	21 ± 17.40	17 ± 15.08	97 ± 61.37	59 ± 31.49	38 ± 23.25	9 ± 9.93	21 ± 32.46	18 ± 33.58	21 ± 24.87	-	-	-
C.ecornis	22 ± 11.39	25 ± 36.07	37 ± 32.84	42 ± 65.98	37 ± 59.36	13 ± 11.36	33 ± 28.83	43 ± 38.52	32 ± 23.49	-	-	-
C.constricta	59 ± 50.75	32 ± 30.02	55 ± 37.74	29 ± 20.95	12 ± 15.85	18 ± 15.44	39 ± 12.15	22 ± 11.18	11 ± 20.75	32 ± 33.53	-	-
C.stellata	-	-	21 ± 50.76	11 ± 32.73	22 ± 43.15	3 ± 9.81	-	-	-	-	-	-
Centropyxis sp.	-	-	12 ± 28.04	9 ± 10.33	14 ± 24.96	5 ± 18.19	-	-	-	-	-	-
Total Centropyxis	117 ± 54.29	85 ± 75.91	334 ± 148.44	256 ± 105.17	200 ± 113.17	71 ± 34.58	159 ± 53.51	104 ± 76.50	92 ± 51.71	53 ± 24.12	-	-
Lesquereusia spiralis	-	-	-	-	-	-	-	-	23 ± 23.63	33 ± 22.23	13 ± 20.90	-
L.modesta	-	-	-	-	-	-	-	-	45 ± 29.17	25 ± 54.18	7 ± 23.52	-
Lesquereusia sp.	-	-	-	-	-	-	-	-	21 ± 26.30	12 ± 27.54	3 ± 11.26	-
Total Lesquereusia	-	-	-	-	-	-	-	-	89 ± 32.46	70 ± 42.06	23 ± 38.91	-
Euglypha sp.	33 ± 40.82	42 ± 50.90	63 ± 70.15	29 ± 41.45	22 ± 33.19	19 ± 30.21	9 ± 31.18	8 ± 20.45	-	-	-	32 ± 26.86
Pareuglypha reticulata	33 ± 35.25	-	-	-	-	-	-	-	-	-	17 ± 31.90	-
Bullinula indica	-	-	18 ± 28.83	9 ± 21.45	13 ± 17.28	-	-	-	-	-	-	-
Plagiopyxis labiata	-	-	28 ± 58.55	31 ± 39.88	-	-	-	-	-	-	-	-
Pyxidicula operculata	-	25 ± 38.64	28 ± 54.28	23 ± 36.92	23 ± 26.92	-	-	-	-	-	-	-
Nebela flabellulum	-	17 ± 38.17	8 ± 19.24	-	-	-	32 ± 27.84	31 ± 36.51	44 ± 19.38	21 ± 14.27	-	-
Astramoeba radiosa	-	5 ± 17.05	-	18 ± 31.55	-	12 ± 29.09	-	-	-	-	-	-
Amoeba discoides	-	-	-	-	-	-	-	-	-	22 ± 28.11	7 ± 15.49	-
Actinophrys sp.	-	-	12 ± 30.82	-	-	-	-	-	-	-	-	-
Total Sarcodina	369 ± 108.71	445 ± 178.05	1120 ± 382.66	756 ± 218.02	389 ± 219.45	238 ± 108.78	395 ± 161.90	322 ± 158.84	288 ± 104.67	264 ± 88.17	47 ± 57.43	104 ± 57.34
Class Ciliata												
Paramecium caudatum	35 ± 30.78	42 ± 57.41	21 ± 28.96	15 ± 18.67	-	-	23 ± 42.00	-	-	-	12 ± 22.90	-
P.bursaria	36 ± 21.56	39 ± 59.81	12 ± 23.44	21 ± 35.62	-	-	-	-	-	-	-	-
P.aurelia	12 ± 26.36	8 ± 28.00	-	-	-	-	-	-	-	-	-	-
P.multimicronucleatum	52 ± 34.10	31 ± 67.18	18 ± 12.34	12 ± 42.44	42 ± 23.87	-	-	-	-	-	-	-
Total Paramecium	*133 ± 43.93*	*120 ± 108.50*	*51 ± 24.86*	*48 ± 85.58*	*42 ± 23.87*	-	*23 ± 42.00*	-	-	-	*12 ± 22.90*	-
Uronema sp.	-	-	-	-	-	12 ± 15.58	-	24 ± 48.48	-	-	-	-
Urocentrum sp.	-	21 ± 39.20	23 ± 39.21	19 ± 29.15	13 ± 16.81	-	-	-	-	-	-	-
Coleps sp.	-	-	56 ± 99.45	26 ± 15.14	19 ± 18.33	7 ± 17.80	-	-	12 ± 18.79	9 ± 16.81	-	-
Lionotus sp.	-	6 ± 16.20	-	-	-	-	-	-	-	11 ± 10.14	-	-
Chilodonella sp.	-	-	-	-	-	-	-	-	-	-	-	-
Homalozoon sp.	-	-	17 ± 43.18	15 ± 21.66	-	-	-	-	-	-	-	-
Euplotes sp.	22 ± 24.73	61 ± 55.98	76 ± 66.92	92 ± 31.42	35 ± 26.66	-	-	-	24 ± 28.06	10 ± 13.92	-	22 ± 9.05
Stylonichia sp.	-	29 ± 51.71	22 ± 40.25	18 ± 20.46	-	-	33 ± 32.55	23 ± 25.97	26 ± 26.49	-	-	-
Condylostoma sp.	-	51 ± 111.71	37 ± 53.30	7 ± 15.09	12 ± 24.47	-	-	-	-	-	-	-
Halteria sp.	-	-	-	-	-	-	22 ± 21.38	14 ± 22.99	17 ± 26.43	-	-	-
Vorticella sp.	-	27 ± 41.30	39 ± 70.87	-	-	-	34 ± 15.99	31 ± 9.69	21 ± 26.44	20 ± 14.66	-	-
Carchesium sp.	-	-	18 ± 35.06	21 ± 38.61	24 ± 33.82	17 ± 22.14	-	-	-	-	-	-
Total Ciliata	155 ± 54.02	315 ± 285.84	339 ± 215.71	246 ± 117.34	145 ± 78.28	36 ± 39.19	112 ± 60.31	92 ± 53.01	100 ± 49.41	50 ± 35.14	12 ± 22.90	22 ± 9.05
TOTAL PROTOZOANS	539 ± 147.10	857 ± 350.41	1540 ± 554.73	1057 ± 335.37	546 ± 283.95	274 ± 132.19	510 ± 206.79	453 ± 172.46	403 ± 159.75	314 ± 101.55	59 ± 53.18	126 ± 60.54

Quantitatively, the order of dominance of various classes of protozoans has been observed as Sarcodina (47±57.43 to 1120±382.66n/l) > Ciliata (12±22.90 to 339±215.71n/l) and > Mastigophora (nil to 97±59.06n/l), during the year 2002-03 (Table I) . In the subsequent year viz. 2003-04, the order of quantitative dominance of various classes of protozoans has been noticed as Ciliata (42±24.38 to 1249±289.32n/l) > Sarcodina (282±112.62 to 1201±558.55n/l) and > Mastigophora (nil to 88±71.15n/l) from Surinsar lake water (Table 2).

During the first year of study, quantitatively, the order of dominance of various genera, belonging to class Mastigophora, has been noticed as *Phacus* (nil to 54±65.17n/l) > *Chlamydomonas* (nil to 34±81.40n/l) and > *Euglena* (nil to 26±14.49n/l). In the subsequent year, the order of quantitative dominance of various genera has been observed as *Chlamydomonas* (nil to 55±15.63n/l) >*Phacus* (nil to 29±31.70n/l) >and > *Euglena* (nil to 29±31.70 n/l).

Seasonally, class Mastigophora, among various classes of Phylum Protozoa, showed bimodal viz March and September/April and September peaks, during the year 2002-03/2003-04. These recorded March/April highest and July, November and December/July, August and November absence(Table 1 and 2 and Fig. 1a).

The order of quantitative dominance of various genera belonging to Class Sarcodina, during the year 2002-03, has been observed as *Arcella* (nil to 473±178.67n/l) > *Centropyxis* (nil to 334±148.44n/l) > *Difflugia*(nil to 203±66.10n/l) >*Lesquereusia* (nil to 89±32.46n/l)> *Euglypha* (nil to 63±70.15n/l) > *Nebela* (nil to 44±19.88n/l) > *Pareuglypha* (nil to 33±35.25n/l) > *Plagiopyxis* (nil to 28±58.55n/l) and *Pyxidicula* (nil to 28±54.28n/l) >*Amoeba* (nil to 22±28.11n/l) > *Astramoeba* (nil to

Table 2. Mean monthly variations in Protozoa of Surinsar Lake, Jammu. (Feb 2003-Jan 2004)

Name of the species	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
PROTOZOA												
Class Mastigophora												
Euglena sp.	26 ± 22.39	23 ± 22.54	27 ± 21.49	12 ± 19.10	14 ± 17.12	-	-	28 ± 28.40	11 ± 17.97	-	21 ± 21.71	9 ± 15.73
Chlamydomonas sp.	-	-	39 ± 27.10	55 ± 15.63	-	-	-	-	-	-	-	16 ± 16.22
Phacus sp.	-	29 ± 31.70	22 ± 29.27	16 ± 28.46	-	-	-	-	-	-	-	-
Total Mastigophora	26 ± 22.39	52 ± 41.07	88 ± 71.15	83 ± 31.07	14 ± 17.12	0 ± 0.00	0 ± 0.00	28 ± 28.40	11 ± 17.97	0 ± 0.00	21 ± 21.71	25 ± 20.04
Class Sarcodina												
Arcella discoides	49 ± 37.96	95 ± 23.61	73 ± 46.93	66 ± 20.14	26 ± 20.72	-	47 ± 19.40	49 ± 37.09	21 ± 15.99	66 ± 48.46	92 ± 38.79	29 ± 22.97
A.vulgaris	48 ± 14.72	85 ± 39.18	78 ± 57.72	53 ± 26.24	-	10 ± 18.52	27 ± 11.24	46 ± 41.45	29 ± 11.94	75 ± 21.48	43 ± 37.46	36 ± 12.74
A.polypora	-	3 ± 6.55	84 ± 136.99	-	-	-	-	-	-	-	-	-
A.megastoma	-	65 ± 19.89	53 ± 59.17	47 ± 26.07	-	-	-	27 ± 28.70	22 ± 10.14	-	-	-
A.dentata	130 ± 62.75	194 ± 81.89	118 ± 118.96	47 ± 10.84	-	8 ± 16.78	18 ± 19.32	-	-	-	21 ± 34.76	18 ± 19.75
Arcella sp.	0 ± 0.00	39 ± 67.77	17 ± 32.44	8 ± 21.03	-	-	-	-	-	-	-	-
Total Arcella	226 ± 96.08	471 ± 106.47	423 ± 240.81	221 ± 35.07	26 ± 20.72	18 ± 21.11	92 ± 21.54	122 ± 56.48	72 ± 21.16	139 ± 61.98	156 ± 64.32	83 ± 36.22
Difflugia urceolata	34 ± 21.92	53 ± 28.79	57 ± 37.34	52 ± 22.52	35 ± 36.55	16 ± 15.85	39 ± 30.15	37 ± 36.22	59 ± 17.88	13 ± 27.63	38 ± 20.38	39 ± 12.53
D.acuminata	31 ± 19.09	67 ± 28.85	89 ± 61.08	64 ± 15.86	72 ± 23.16	9 ± 14.63	28 ± 25.45	48 ± 41.56	72 ± 26.45	6 ± 15.91	37 ± 33.74	27 ± 27.47
D.oblonga	12 ± 13.18	37 ± 35.49	133 ± 112.06	65 ± 36.62	34 ± 29.53	31 ± 12.71	55 ± 34.20	33 ± 16.11	48 ± 9.60	-	35 ± 36.64	21 ± 16.96
D.corona	14 ± 13.44	4 ± 14.43	-	-	21 ± 40.00	8 ± 13.56	38 ± 39.65	41 ± 41.39	-	-	44 ± 54.40	12 ± 22.56
D.lebes	31 ± 32.07	4 ± 13.57	18 ± 32.83	28 ± 37.71	16 ± 22.05	-	-	19 ± 13.24	28 ± 13.97	-	37 ± 21.10	18 ± 18.80
D.rubescens	-	6 ± 11.06	-	-	-	-	-	21 ± 26.91	75 ± 36.66	-	-	10 ± 17.97
D.tuberculata	8 ± 26.27	-	-	38 ± 8.66	-	-	-	-	-	-	-	26 ± 21.20
Difflugia sp.	-	-	-	-	-	-	-	15 ± 20.41	19 ± 26.65	-	-	8 ± 19.46
Total Difflugia	130 ± 51.50	171 ± 54.50	277 ± 149.18	247 ± 54.27	178 ± 84.66	64 ± 30.86	160 ± 77.25	214 ± 75.35	301 ± 64.40	19 ± 28.88	191 ± 48.62	161 ± 41.45
Centropyxis aculeata	63 ± 25.31	84 ± 21.12	103 ± 130.27	88 ± 22.47	81 ± 33.24	20 ± 37.57	64 ± 26.86	49 ± 28.46	85 ± 38.10	57 ± 51.80	96 ± 61.68	109 ± 60.10
C.hemisphaerica	40 ± 14.59	32 ± 6.85	85 ± 78.96	53 ± 45.43	40 ± 35.07	-	-	41 ± 52.01	23 ± 25.22	73 ± 15.61	33 ± 27.45	26 ± 15.84
C.ecornis	72 ± 40.12	42 ± 21.43	48 ± 52.39	32 ± 30.02	46 ± 34.99	18 ± 19.02	39 ± 42.00	99 ± 58.13	93 ± 24.34	-	58 ± 49.59	45 ± 39.35
C.constricta	250 ± 93.28	29 ± 24.43	68 ± 64.39	44 ± 28.74	-	20 ± 24.38	46 ± 46.29	47 ± 38.71	120 ± 54.30	51 ± 30.78	52 ± 24.40	36 ± 13.89
C.stellata	105 ± 75.04	6 ± 9.54	16 ± 20.44	4 ± 13.86	32 ± 19.74	-	-	-	-	-	-	14 ± 34.10
Centopyxis sp.	-	-	-	8 ± 14.14	27 ± 29.51	13 ± 27.63	12 ± 41.28	-	59 ± 42.23	-	32 ± 32.49	42 ± 28.52
Total Centropyxis	532 ± 130.22	193 ± 41.97	320 ± 264.07	229 ± 42.67	226 ± 74.41	71 ± 74.52	161 ± 67.31	236 ± 93.98	380 ± 96.47	181 ± 69.52	271 ± 79.59	272 ± 111.85
Lesquereusia spiralis	26 ± 11.77	4 ± 9.74	18 ± 22.69	-	-	21 ± 31.45	37 ± 26.05	-	-	-	-	-
L.modesta	21 ± 15.08	8 ± 11.79	-	15 ± 24.03	21 ± 15.64	25 ± 7.97	-	-	39 ± 62.21	26 ± 7.79	21 ± 27.44	-
Lesquereusia sp.	-	11 ± 16.66	9 ± 21.63	21 ± 33.74	-	-	-	-	-	-	-	-
Total Lesquerrusia	47 ± 22.59	23 ± 21.05	27 ± 34.04	36 ± 33.12	21 ± 15.64	46 ± 31.01	37 ± 26.05	-	39 ± 62.21	26 ± 7.79	21 ± 27.44	-
Euglypha sp.	-	37 ± 15.08	38 ± 57.45	35 ± 34.68	53 ± 40.25	19 ± 17.56	44 ± 37.99	124 ± 88.51	92 ± 24.41	66 ± 29.41	41 ± 30.23	22 ± 23.71
Pareuglypha reticulata	-	-	-	-	-	-	-	-	-	-	-	16 ± 19.76
Bullinula indica	-	-	23 ± 43.90	16 ± 21.22	-	15 ± 18.33	16 ± 19.64	20 ± 23.93	-	-	-	-
Plagiopyxis labiata	42 ± 34.33	8 ± 12.79	21 ± 42.61	8 ± 14.47	-	-	-	26 ± 16.43	33 ± 30.30	-	-	8 ± 15.98
Pyxidicula operculata	-	22 ± 21.75	32 ± 71.52	23 ± 31.66	37 ± 22.76	21 ± 25.79	-	31 ± 18.93	-	-	-	-
Nebela flabellulum	-	17 ± 16.66	8 ± 29.16	-	-	19 ± 15.69	28 ± 17.84	15 ± 19.95	-	-	-	-
Astramoeba radiosa	-	2 ± 8.08	-	-	21 ± 25.48	-	-	11 ± 15.25	-	-	21 ± 34.46	7 ± 11.78
Amoeba discoides	-	4 ± 8.78	9 ± 31.47	-	6 ± 13.78	-	-	21 ± 28.26	21 ± 29.44	-	15 ± 24.62	13 ± 21.08
Actinophrys sp.	-	6 ± 14.90	23 ± 35.82	-	-	9 ± 21.87	-	-	-	-	-	6 ± 14.86
Total Sarcodina	977 ± 250.78	954 ± 193.14	1201 ± 558.55	815 ± 133.20	568 ± 133.10	282 ± 112.65	538 ± 124.71	820 ± 233.97	938 ± 145.99	431 ± 114.11	716 ± 184.01	588 ± 167.85
Class Ciliata												
Paramecium caudatum	-	39 ± 30.08	125 ± 127.02	112 ± 60.19	-	9 ± 11.93	21 ± 25.16	54 ± 26.53	145 ± 67.16	52 ± 41.64	109 ± 36.88	29 ± 29.69
P.bursaria	-	15 ± 16.89	59 ± 69.45	55 ± 48.80	-	-	-	-	-	-	-	-
P.aurelia	-	18 ± 41.66	43 ± 52.54	22 ± 23.69	-	-	-	-	-	-	-	-
P.multimicronucleatum	42 ± 24.38	49 ± 17.94	72 ± 19.58	88 ± 35.65	37 ± 40.70	19 ± 14.74	36 ± 29.51	43 ± 21.57	59 ± 28.52	33 ± 31.26	74 ± 30.00	39 ± 29.62
Total Paramecium	*42 ± 24.38*	*121 ± 51.22*	*299 ± 215.58*	*277 ± 56.84*	*37 ± 40.70*	*28 ± 12.04*	*57 ± 26.05*	*97 ± 31.83*	*204 ± 81.96*	*85 ± 53.47*	*183 ± 55.74*	*68 ± 42.25*
Uronema sp.	-	12 ± 13.18	155 ± 63.81	92 ± 54.88	-	-	-	-	-	-	-	-
Urocentrum sp.	-	58 ± 43.57	94 ± 104.11	73 ± 34.93	30 ± 25.68	28 ± 14.89	48 ± 25.06	39 ± 32.11	67 ± 24.57	-	75 ± 15.74	23 ± 30.09
Coleps sp.	-	-	177 ± 75.96	156 ± 60.58	32 ± 20.79	19 ± 23.85	16 ± 21.35	-	73 ± 27.64	37 ± 18.68	-	23 ± 21.86
Lionotus sp.	-	8 ± 13.86	-	98 ± 39.76	26 ± 31.18	-	-	22 ± 21.21	-	-	-	-
Chilodonella sp.	-	-	21 ± 38.83	32 ± 30.45	-	-	-	25 ± 21.03	-	-	-	-
Homalozoon sp.	-	35 ± 18.56	79 ± 27.23	39 ± 29.37	-	-	-	-	-	-	-	-
Euplotes sp.	-	73 ± 53.48	168 ± 84.19	144 ± 57.53	36 ± 18.81	-	-	52 ± 27.67	48 ± 41.77	22 ± 25.96	82 ± 23.70	29 ± 27.61
Stylonchia sp.	-	33 ± 30.54	32 ± 35.73	44 ± 22.00	-	18 ± 33.89	21 ± 24.89	31 ± 31.81	68 ± 30.65	38 ± 20.73	63 ± 14.23	-
Condylostoma sp.	-	74 ± 19.49	46 ± 31.57	33 ± 27.25	-	-	-	-	-	-	-	-
Halteria sp.	-	-	26 ± 34.02	22 ± 8.88	-	-	-	-	-	41 ± 41.26	129 ± 38.39	65 ± 25.97
Vorticella sp.	-	14 ± 14.66	104 ± 35.31	89 ± 48.05	-	-	59 ± 19.29	56 ± 25.18	83 ± 32.21	42 ± 38.02	26 ± 32.82	96 ± 46.61
Carchesium sp.	-	-	68 ± 15.85	36 ± 49.95	34 ± 13.52	39 ± 15.86	59 ± 24.51	-	-	-	36 ± 21.85	-
Total Ciliata	42 ± 24.38	428 ± 109.53	1249 ± 289.32	1135 ± 178.88	195 ± 92.32	132 ± 47.06	260 ± 57.47	322 ± 67.69	543 ± 115.15	265 ± 114.05	594 ± 90.38	304 ± 92.93
TOTAL PROTOZOAN	1045 ± 268.83	1434 ± 281.24	2538 ± 783.40	2033 ± 290.17	777 ± 165.20	414 ± 125.49	798 ± 155.88	1170 ± 301.11	1492 ± 188.05	696 ± 209.03	1331 ± 236.71	917 ± 234.02

18±31.55n/l) and *Bullinula* (nil to 18±28.83) and > *Actinophrys* (nil to 12±30.82n/l). Quantitatively, during the subsequent year viz. 2003-04, the order of dominance of various genera belonging to Class Sarcodina has been noticed as *Arcella* (18±21.11 to 471±106.47n/l) > *Centropyxis* (71±74.32 to 380±96.47n/l) > *Difflugia* (19±28.88 to 301±64.40n/l) > *Euglypha* (nil to 124±88.51n/l) > *Lesquereusia* (nil to 47±22.59n/l) > *Plagiopyxis (*nil to 42±34.33n/l) > *Pyxidicula* (nil to 37±22.76n/l) > *Nebela* (nil to 28±17.84n/l) > > *Bullinula* (nil to 23±43.90n/l) and *Actinophrys* (nil to 23±35.82n/l) >*Amoeba* (nil to 21±28.26n/l) and *Astramoeba* (nil to 21±25.48n/l) and > *Pareuglypha* (nil to 16±27.22n/l).

Class Sarcodina, during the first year, showed bimodal viz. April and August peak, with a trough during July and December. It observed April highest and December lowest record(Table 1 and Fig. 1b). In the subsequent year, class Sarcodina observed an increase during April, October and December and trough during July and November. It recorded highest and lowest record during April and July, respectively (Table 2 and Fig.1b).

Among class Ciliata, during the first year, the order of quantitative dominance of various genera has been observed as *Paramecium* (nil to 133±43.93n/l) > *Euplotes* (nil to 92±31.42n/l) > *Coleps* (nil to 56±49.45n/l) > *Condylostoma* (nil to 51±111.71n/l) >*Vorticella* (nil to 39±70.87n/l) > *Stylonychia* (nil to 29±51.71n/l) > *Uronema* (nil to 24±48.48n/l) and *Carchesium* (nil to 24±33.82n/l) > *Urocentrum* (nil to 23±39.21n/l) > *Halteria* (nil to 22±21.38n/l) > *Homalozoon* (nil to 17±43.18n/l) and > *Lionotus* (nil to 11±10.14n/l). The order of quantitative dominance of various genera of class ciliata, during the subsequent year, has been noticed as *Paramecium* (37±40.70 to 299±215.58n/l) > *Coleps* (nil to 177±75.96n/l) > *Euplotes* (nil to 168±n/l) > *Uronema* (nil to 135±n/l) > *Halteria*(nil to 129±n/l) > *Vorticella* (nil to 104±35.31n/l) > *Lionotus* (nil to 98±39.76n/l) > *Urocentrum* (nil to 94±104.11n/l)>*Homalozoon* (nil to 79±27.23n/l)>*Condylostoma* (nil to 74±19.47n/l) > *Stylonychia* (nil to 68±30.65n/l) and *Carchesium* (nil to 68±15.85n/l) and > *Chilodonella* (nil to32±39.45 n/l).

Class Ciliata, during the first year, recorded summer (March, April and May) quantitative increase with constant decrease during November, December and January. These recorded highest and lowest record during April and December, respectively (Table 1 and Fig. 1c). In the subsequent year, ciliates showed April, October and December peaks. These observed April highest and February lowest record (Table 2 and Fig. 1c).

Seasonally, total protozoans, have shown April and August peak and December and January trough, during the first year. These recorded April highest and December lowest quantitative count (Table 1 and Fig. 1d). In the subsequent year, protozoans recorded trimodal viz. April, October and December peaks with April highest and July lowest record. These recorded July and November trough (Table 2 and Fig. 1d).

Summer (March-May), qualitative and quantitative increase of protozoans, during both the years of study, is in accordance with the findings of Chourasia and Adoni (1985), Dutta *et al*.(1990, 1991), Katiyar and Belsare (1997), Wetzel(2000) and Narayana and Somashekhar (2002) and may be attributed to- i) increased multiplication at higher temperature (Sehgal, 1980; Kumar, 1990; Katiyar, 1995; Katiyar and Balsare, 1997; Dutta and Sharma, 2000; Sharma, 2000, and Narayana and Somashekhar, 2002), ii) rise in pH. A direct relationship between protozoan density and pH is already on record (Rai and Sharma,1986). iii) enrichment of organic matter and dissolved solids due to accelerated decomposition of aquatic vegetation (Kudo,1986; Kaushik and Saksena,1995; Katiyar and Belsare,1997; Pandit, 1999 and Wetzel, 2000), at higher temperature, iv) summer upward migration of some rhizopod protozoans due to fat inclusions(Wetzel, 2000 and Hutchinson, 2004) and gas bubbles(Cole, 1975; Reid and Wood, 1976; Wetzel, 2000 and Hutchinson , 2004).

Dilution, depletion of food and increased turbulence, during monsoon, may account for July low protozoan count in lake water, during both the years of study and is in conformity with the observations of Vashisht and Jindal(1980), Jindal and Vasisht(1985), Dutta *et al*.(1990 and 1991) and Narayana and Somasekhar (2002).

Winter viz., December, January/November and January low quantitative count of protozoans, during the year 2002-03/2003-04, has its correlation with- i) winter overturn which results in uniform mixing of protozoans and hence their reduction in the surface waters, ii) presence of low concentration of DO and rise in free CO_2 (Jindal and Vasisht, 1985 and Dutta *et al*., 1990). iii) sinking of some protozoans (*Difflugia*) to the bottom layers due to metabolization of fat gloubulets during winter (Wetzel, 2000).

Ecological distribution of protozoans has been discussed earlier by many workers. Chourasia and Adoni(1985), Mishra and Saksena(1990), Sleigh *et al*.(1992) and Pandit(2000) have recorded a positive correlation between temperature and protozoans. Jindal and Vasisht(1985) and Patra and Dutta(2004) correlated protozoans abundance with moderate temperature and higher record of DO. Rai and Sharma(1986) worked out positive correlation between the total protozoan count and chemical factors like pH, DO, bicarbonate, alkalinity etc. Dutta *et al*.(1990) found rise in temperature, high value of pH, DO, calcium, and total hardness favourable for quantitative rise in protozoans in some pools adjacent to river Tawi, Jammu. Dutta *et al*. (1991) worked out rise in temperature, rise in pH, low bicarbonate, calcium, magnesium and total hardness favouring protozoan abundance in Kunjwani pond, Jammu. Narayana and Somashekhar(2002) reported positive correlation between protozoans and temperature, phosphates and nitrates. Katiyar and Belsare(1997) recorded positive correlation between total protozoans and nitrate and phosphate, during summers, from Bhopal lakes.

Table 3. Coefficient of correlation(r) between Protozoans and various physico-chemical parameters of Surinsar Lake, Jammu (Feb. 2002-Jan. 2004).

Parameters	(r)2002-03	(r)2003-04
Water Temperature	0.22	-0.25
Depth	0.07	-0.03
Turbidity	0.74	0.10
Salinity	0.04	0.23
Electric Conductivity	0.06	0.03
TDS	-0.03	0.11
pH	0.32	-0.42
Free CO_2	0.63	0.04
Dissolved Oxygen	-0.54	0.22
Carbonate (CO_3^{2-})	-0.36	0.29
Bicarbonate (HCO_3^-)	-0.36	0.23
Chloride (Cl^-)	-0.36	-0.02
Calcium (Ca^{2+})	-0.31	-0.09
Magnesium (Mg^{2+})	0.10	-0.24
Total Hardness	0.22	0.37
BOD	-0.54	0.49
COD	0.75	-0.32
Sodium(Na^+)	0.15	0.51
Potassium (K^+)	0.03	-0.29
Phosphate(PO_4^{3-})	-0.62	0.09
Nitrate (NO_3^-)	0.59	-0.35
Sulphate (SO_4^{2-})	-0.13	-0.10
Silicate (SiO_2)	-0.18	-0.38
Iron (Fe^{2+})	-0.28	-0.04

Table 4. ANOVA test for various Classes of Protozoans (Feb. 2002-Jan. 2004).

Groups	Count	Sum	Average	Variance
Total Mastigophora	12	317	26.42	1158.63
Total Sarcodina	12	4737	394.75	83957.30
Total Ciliata	12	1624	135.33	12305.70

ANOVA

Source of Variation	SS	df	MS	F_{obs}	F_{crit}
Between Groups	859317.17	2	429658.583	13.23	3.28
Within Groups	1071637.83	33	32473.8737		
Total	**1930955**	**35**			

(Feb 2003-Jan 2004)

Groups	Count	Sum	Average	Variance
Total Mastigophora	12	348.04	29.00	917.07
Total Sarcodina	12	8827.56	735.63	69541.71
Total Ciliata	12	5468.67	455.72	143455.65

ANOVA

Source of Variation	SS	df	MS	F_{obs}	F_{crit}
Between Groups	3039033.60	2	1519516.80	21.31	3.28
Within Groups	2353058.80	33	71304.81		
Total	**5392092.40**	**35**			

Where , SS= Sum of Squares, df= degree of freedom, MS= Mean Square(SS/df), Fobs= observed value of F, Fcrit= critical value obtained from the F distribution table at 5% level.

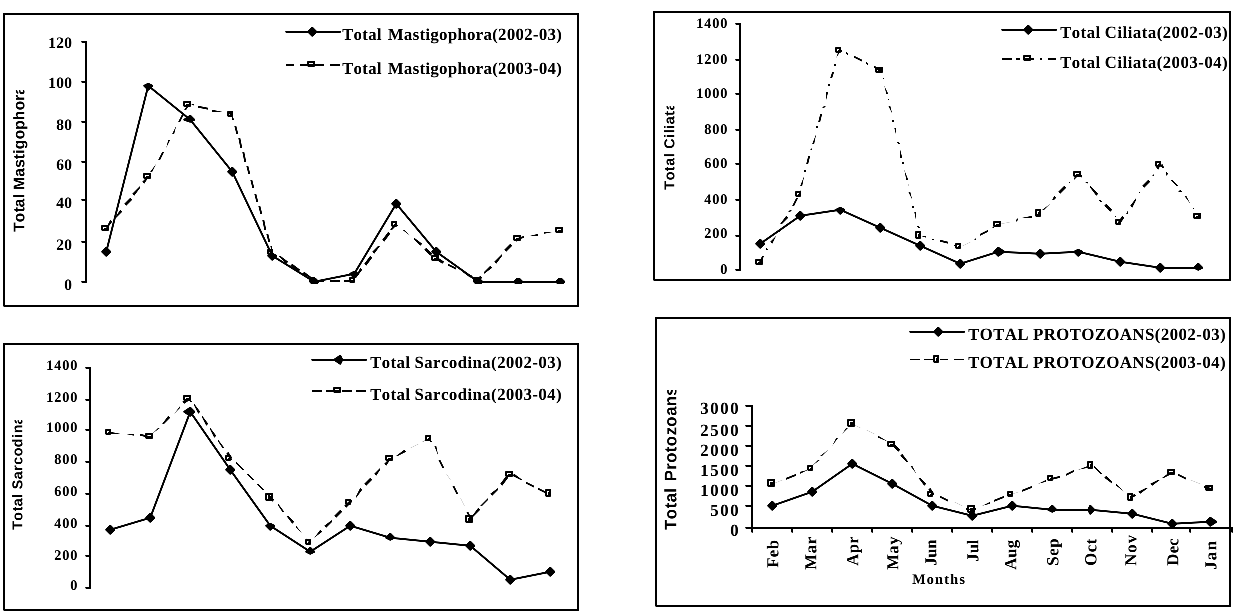

Fig. 1. Mean monthly variations in total mastigophora, total sarcodina, total ciliata and total protozoa of Surinsar Lake, Jammu.

Analysis of coefficient of correlation of protozoans, with different physico-chemical parameters of Surinsar Lake water has shown significant results with pH, free CO_2, carbonate, BOD, COD, phosphate and nitrate only, during the year 2002-03. In the subsequent year viz. 2003-04, coefficient of correlation analysis (r) of total protozoan with various physico-chemical factors of water has generally revealed insignificant correlation except with sodium(Table 3). This strongly indicates that no single factor is a strong determinant for protozoan diversity and density in lake Surinsar , Jammu. Also, one way ANOVA analysis of the means of all the three Classes of protozoans shows that because the calculated value of F is greater than the tabulated value of F at p=0.5(3.28), the calculated value is significant and the means of various classes differ significantly among themselves(Table 4). Thus, all these classes are significant contributor to the total protozoan population.

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